Annular Pressure Buildup (APB) occurs in all wells with high bottomhole temperature, multiple casing strings and annuli that cannot be vented --- which includes most deepwater Gulf of Mexico wells. APB can result in casing string and premature well failure, unless a well is properly designed. APB risks must be fully assessed for all load cases, and any necessary APB mitigation methods are evaluated, fully analyzed for effectiveness, and properly implemented. Managing annular-pressure buildup (APB) for sustaining well deliverability is particularly crucial in subsea wells, where intervention is complicated. Ordinarily, a multistring casing design accommodates anomalous pressure rise from the standpoint of well integrity. Unique challenges are associated with APB management.

Several existing solutions have been presented in past literature. In general, APB mitigation technologies and strategies can be classified as either preventing pressure development or managing the pressure as it develops. The following report provides a summary of the state-of-art of the proposed technologies to be evaluated in the study “Reliability of Annular Pressure Buildup (APB) Mitigation Technologies”. Currently there are a number of technologies that have been used and proven to be successful for APB mitigation.

**Statement and Significance of the Problem**

Annular Pressure Buildup (APB) is a consequence of the difference in the annular fluid volume change and the volume change of the tubing string and multiple casing strings that form the multiple annuli in a well. Annulus fluid volume change may be caused by thermal expansion and/or addition/removal of fluid. An annulus changes its volume in response to fluid pressure and temperature changes while maintaining mechanical equilibrium at all times. Since annuli are not accessible at the wellhead in subsea wells, the pressure build-up in the trapped annular fluids imposes significant loads on the well tubing and casing strings.
Though the physics of APB is well understood and though there are well documented methods of calculating APB, there is significant uncertainty in the assessment of the risk caused by APB. This is partly due to the fact that APB is a function of several variables, chief among them being -

- annular fluid PVT response,
- uncertainties in the thermal models' inputs used to predict wellbore temperatures, and
- second order unknown variables, such as wellbore elasticity, behavior of open-hole sections, and long term behavior of fluids sealed in inaccessible subsea annuli [1], [2]*.

While theoretically sound, most APB assessments must be regarded as a probable range of estimates. Accordingly, casing strings and the wellbore must be designed so that the wellbore is robust enough to ride the uncertainties inherent in APB induced loads.

Wellbore integrity issues in HPHT and deepwater subsea wells can seldom be addressed solely by increasing the tubular strengths [2]. The differential collapse and burst loads on the various tubular strings must be controlled by “deliberate APB management” and by active consideration of APB induced loads in each well's basis of casing design.

The significance of APB induced loads in wellbore design and integrity became apparent after the Marlin incident [3] [4] [5].

**Background and Existing Technologies/Methodologies**

Beginning in the late 1990s, deepwater developments in the GOM began to employ active means of annular pressure management strategies to prevent APB issues. Historically, the most successful annular pressure management strategies included rupture disks on the outer strings, solid syntactic foams, nitrified gas caps and VIT (vacuum insulated tubing). In the early years of the previous decade, these techniques were installed in several GOM developments [2]. In addition to these techniques, methods to relieve APB pressures using the following techniques have been suggested:

- Gas-laden fluids that are engineered to exhibit higher compressibility. The higher compressibility is a result of entraining tiny gas bubbles in a parent liquid, so that the gas bubbles and the liquid are in stable chemical and physical equilibrium at standard temperature and pressure. When these fluids are injected downhole, and when they are subjected to a temperature increase, their higher compressibility should result in a lower pressure rise (as compared with the pressure rise that would be expected if only the parent fluid were present in the annulus).

* Numbers enclosed by square parentheses refer to works cited in section A.3 2. References.
• Hollow glass spheres (HGS), manufactured by companies such as 3M, engineered so that a substantial fraction of them crush at a predetermined pressure when introduced in a fluid filled annulus that is trapped.
• Patented downhole pressure compensators based on mechanical actuators.
• Wellhead access via a hole drilled by an ROV into the surface casing after well completion.
• Polymeric fluids that shrink with temperature increase.
• High performance insulating packer fluids are designed to minimize unwanted heat flow by simultaneously controlling conduction and convection. These fluids restrain heat flow coming from the production tubing to the outer annuli, reducing annular pressure buildup and maintaining flowing well temperatures.
• Lightweight silica solids derived from gel in which the liquid component of the gel has been replaced with gas, resulting in a highly porous with extremely low density solid, most notably for its effectiveness as a thermal insulator.
• Fluids that contain hollow glass microspheres (HGS) have been reported as way to solve APB. The principle of the fluid-bead mixture is not very different from syntactic foam, except that the fluid carries the glass beads rather than a thermoplastic resin.

Some of these techniques have only been conceptually and lab tested to date. Their ability to perform under field conditions is not yet known, uncertain, and/or not widely communicated to the industry.

Criteria Evaluation
The technical basis of an APB mitigation strategy determines its performance, and by extension, its reliability. Therefore it is crucial to understand the technical basis of mitigation strategies. APB mitigation strategies can be classified under two heads -

1. Strategies that manage annular pressures, given that pressure build up is highly likely or inevitable (for example, rupture disks or syntactic foams).

2. Strategies that prevent pressure build-up in the annuli, by either eliminating heat transfer to the annuli (for example in Annulus A, the tubing-casing annulus, using vacuum insulated tubing - VIT), or by altering the contents of the annuli (for example in Annuli B-n, the casing-casing and casing-formation annuli, using insulating fluids, glass beads, special cements, gas laden fluids with stable bubbles, shrinkable fluids, or other methods).

The mitigation strategies may be used on its own, or often combined as multiple mitigation methods.
References


